US009341396B2

(12) **United States Patent**
Manzo

(10) **Patent No.: US 9,341,396 B2**
(45) **Date of Patent: May 17, 2016**

(54) **RETRO-FIT ENERGY EXCHANGE SYSTEM FOR TRANSPARENT INCORPORATION INTO A PLURALITY OF EXISTING ENERGY TRANSFER SYSTEMS**

(75) Inventor: **Aniello Manzo**, Burnaby (CA)

(73) Assignee: **ENERGY RECOVERY SYSTEMS INC.**, Vancouver, BC (CA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 784 days.

(21) Appl. No.: **13/641,540**

(22) PCT Filed: **Apr. 16, 2010**

(86) PCT No.: **PCT/CA2010/000605**

§ 371 (c)(1),
(2), (4) Date: **Oct. 16, 2012**

(87) PCT Pub. No.: **WO2011/127553**

PCT Pub. Date: **Oct. 20, 2011**

(65) **Prior Publication Data**

US 2013/0031933 A1 Feb. 7, 2013

(51) **Int. Cl.**

F25B 29/00	(2006.01)
F24D 19/10	(2006.01)
F24F 11/00	(2006.01)
F25B 49/02	(2006.01)

(52) **U.S. Cl.**

CPC ***F25B 29/003*** (2013.01); ***F24D 19/1006*** (2013.01); ***F24F 11/0009*** (2013.01); *F25B 29/00* (2013.01); *F25B 49/02* (2013.01); *Y10T 137/6416* (2015.04)

(58) **Field of Classification Search**

CPC F25B 29/003; F25B 29/00; F24D 17/0089; F24D 2200/16

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,969,187	A *	8/1934	Schutt	165/236
2,456,386	A *	12/1948	Cooper	62/175
3,922,876	A *	12/1975	Wetherington et al.	62/180
4,098,092	A	7/1978	Singh	
4,141,222	A	2/1979	Ritchie	
4,142,379	A	3/1979	Kuklinski	
4,199,955	A	4/1980	Jonsson	
4,226,606	A *	10/1980	Yaeger et al.	62/238.6
4,238,931	A	12/1980	Campbell	
4,241,588	A	12/1980	Murphy et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

CA	2229355	C	2/1999
CA	2574996	A1	12/2006

(Continued)

OTHER PUBLICATIONS

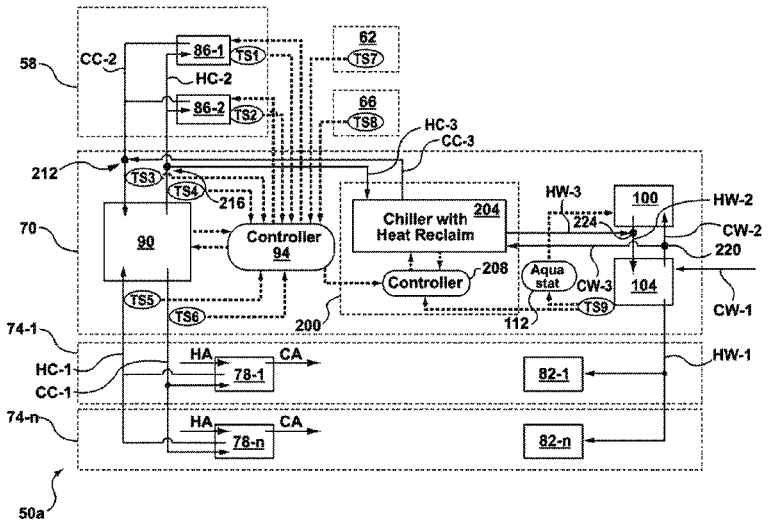
International Search Report and Written Opinion of the International Searching Authority in corresponding International Application PCT/CA2010/000605, mailed Apr. 16, 2010.

Primary Examiner — Ljiljana Ciric
Assistant Examiner — Alexis Cox
(74) *Attorney, Agent, or Firm* — Perry + Currier, INC

(57) **ABSTRACT**

A retrofit energy exchange system including a first set of valves for connecting to a first energy transfer sub-system. The system further includes a second set of valves for connecting to a second energy transfer sub-system. In addition, the system includes an energy exchange unit configured to supply excess energy from to the first energy transfer sub-system to the second energy transfer sub-system.

11 Claims, 7 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

4,281,519	A		8/1981	Spath et al.
4,293,323	A		10/1981	Cohen
4,386,500	A		6/1983	Sigafoose
4,492,092	A		1/1985	Smorol et al.
4,680,941	A		7/1987	Richardson et al.
4,685,307	A		8/1987	Jones
4,732,007	A		3/1988	Dolan et al.
4,773,231	A		9/1988	Sulzberger
5,020,721	A		6/1991	Horne
5,050,394	A	*	9/1991	Dudley et al. 62/115
5,220,807	A		6/1993	Bourne et al.
5,351,502	A		10/1994	Gilles et al.
5,575,159	A		11/1996	Dittell
5,695,004	A		12/1997	Beckwith
5,758,820	A		6/1998	Celorier, Jr. et al.
5,906,104	A		5/1999	Schwartz et al.
5,984,198	A		11/1999	Bennett et al.
8,037,931	B2		10/2011	Penev et al.
2001/0003347	A1	*	6/2001	Shimoda et al. 236/13
2002/0020175	A1	*	2/2002	Street et al. 62/132
2005/0039878	A1	*	2/2005	Meyer et al. 165/42
2005/0066678	A1	*	3/2005	Kamimura 62/238.7
2007/0000262	A1		1/2007	Ikegami et al.
2010/0064710	A1	*	3/2010	Slaughter 62/238.7
2010/0193152	A1		8/2010	Singleton, Jr. et al.
2014/0026608	A1	*	1/2014	Manzo et al. 62/305

FOREIGN PATENT DOCUMENTS

CN	101240949	B	8/2008
GB	2052712		1/1981
WO	2004051148	A1	6/2004

* cited by examiner

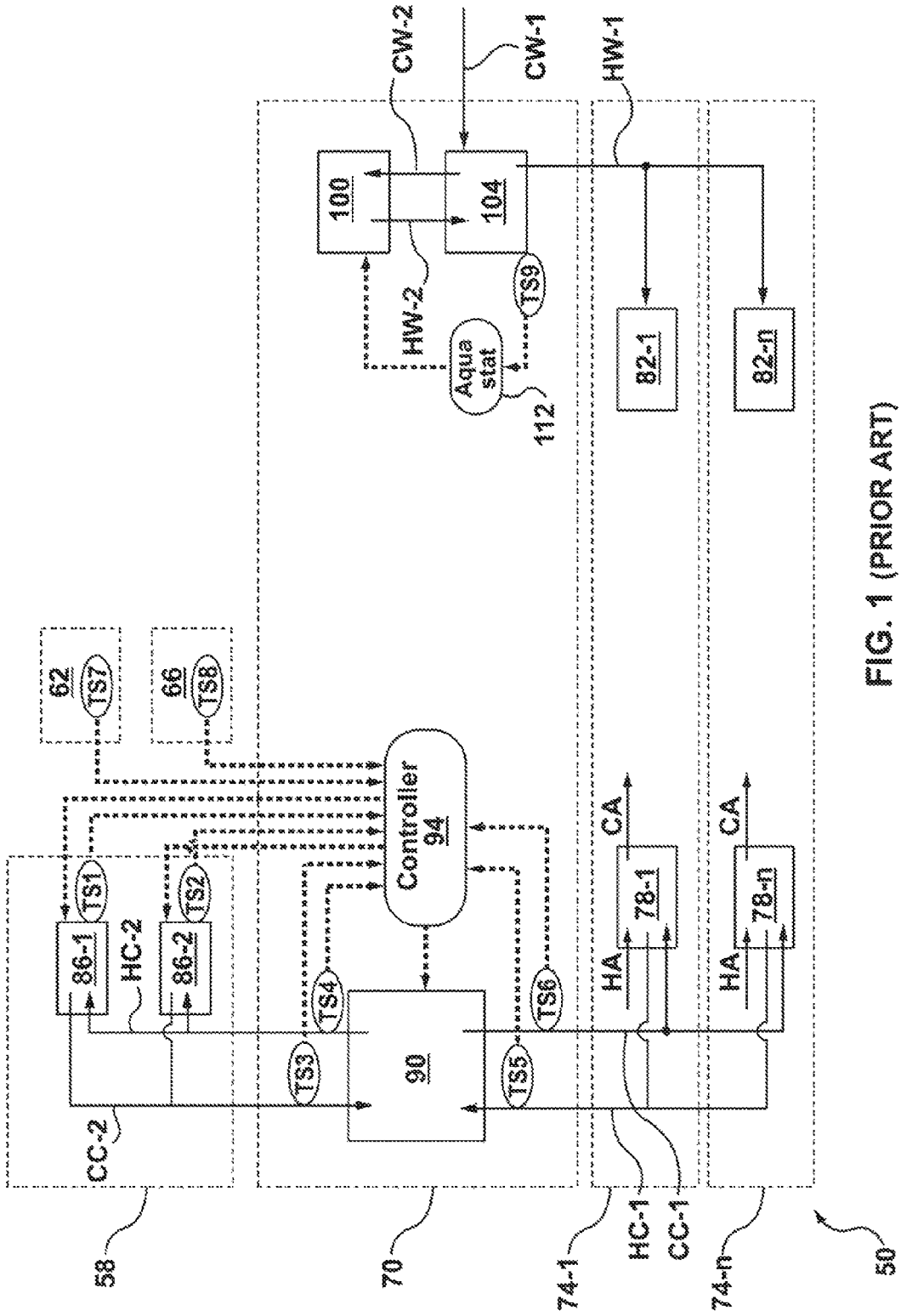


FIG. 1 (PRIOR ART)

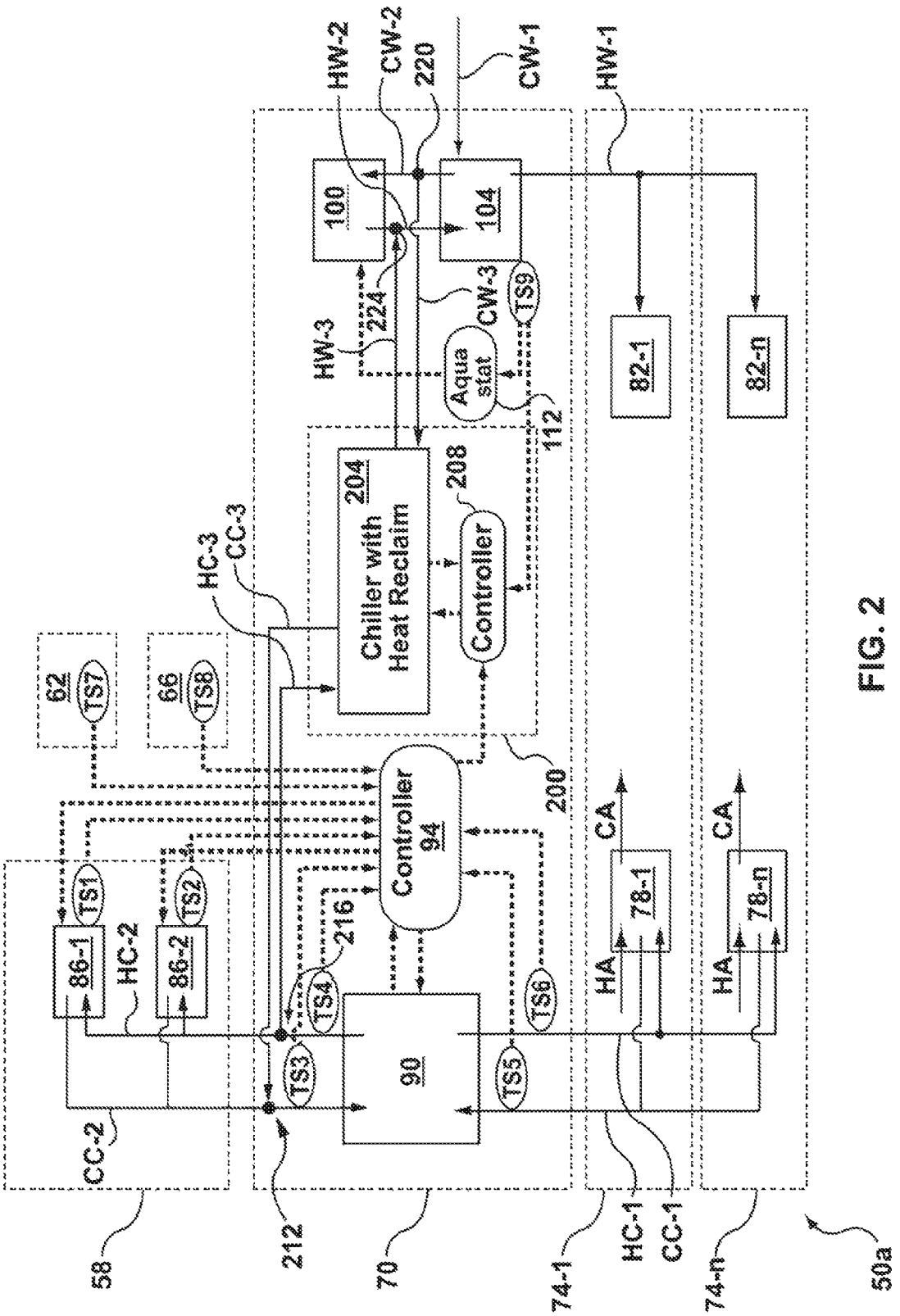

HW-2
CW-2
220
CW-1
HW-1
100
104
HW-3
224
CW-3
TS9
Aqua stat
112
82-1
82-n
204
Chiller with Heat Reclaim
208
Controller
HC-3
CC-3
62
TS7
66
TS8
200
Controller 94
CA
86-1
TS1
HC-2
86-2
TS2
216
78-1
78-n
HA
TS4
TS6
TS3
90
TS5
CC-2
58
212
70
74-1
HC-1
CC-1
74-n
50a

FIG. 2

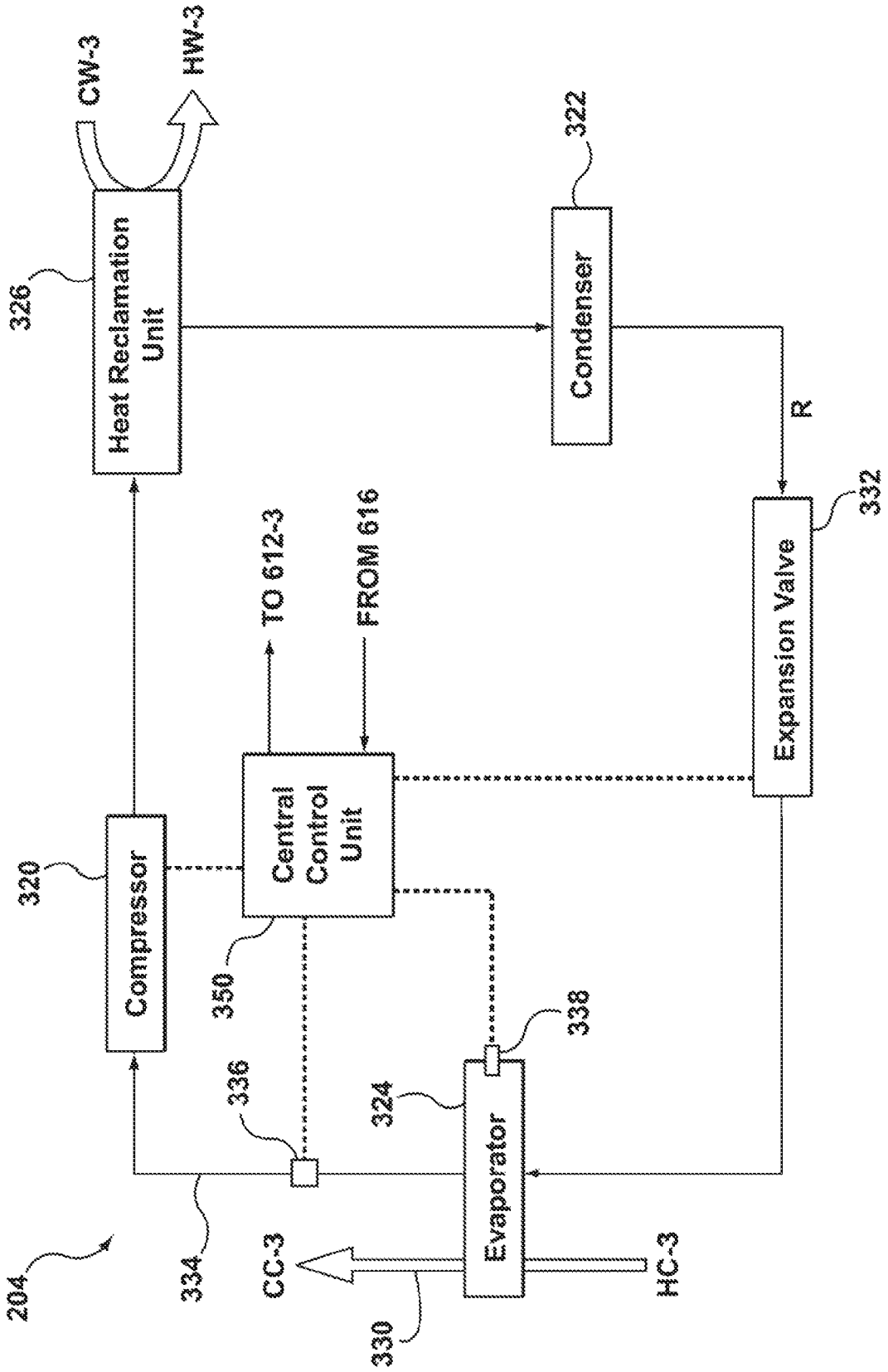

CW-3
HW-3
326
Heat Reclamation Unit
322
Condenser
R
332
Expansion Valve
TO 612-3
FROM 616
Central Control Unit
320
Compressor
350
336
338
324
Evaporator
204
334
CC-3
330
HC-3

FIG. 3

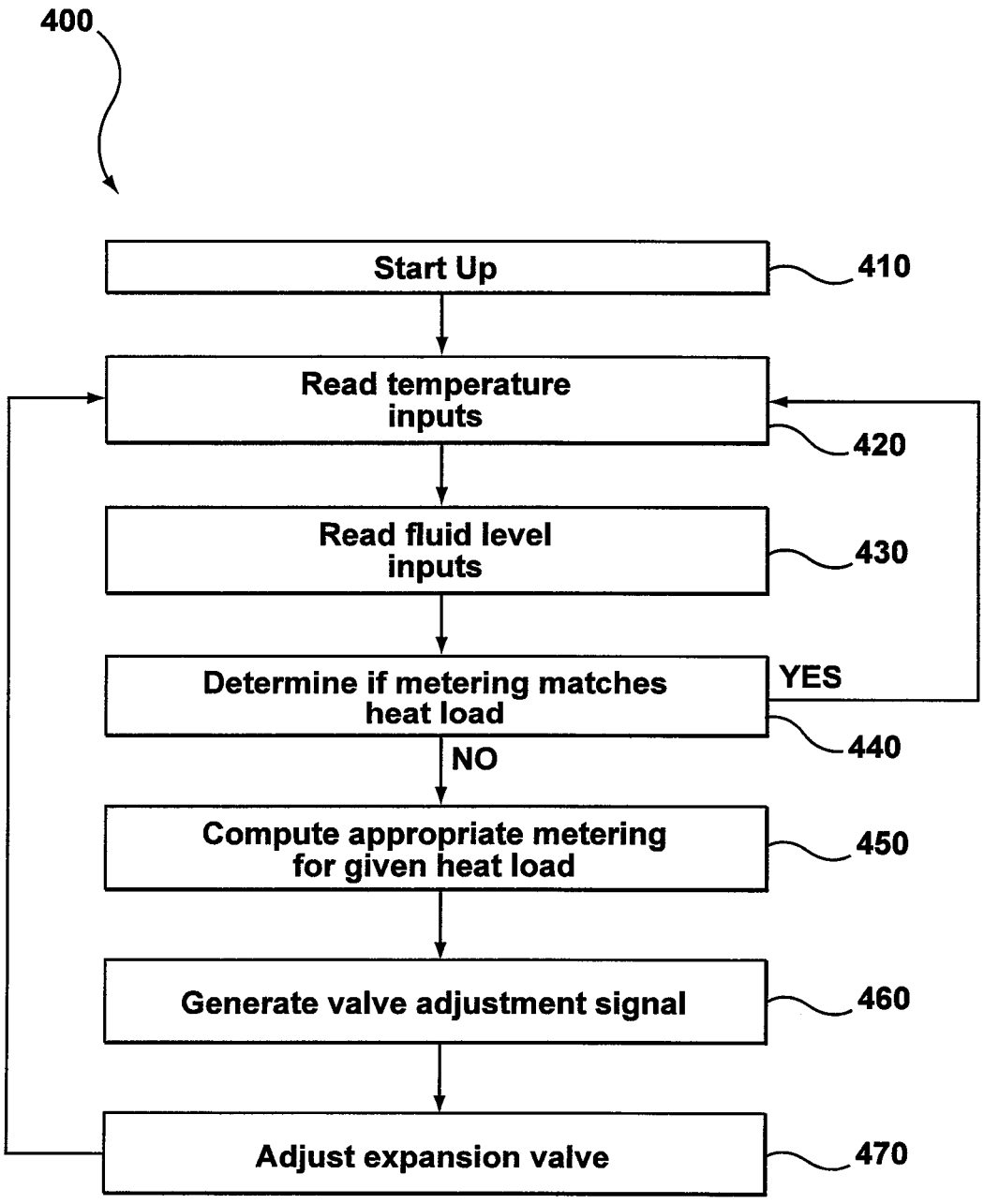

400
Start Up
410
Read temperature inputs
420
Read fluid level inputs
430
Determine if metering matches heat load
YES
440
NO
Compute appropriate metering for given heat load
450
Generate valve adjustment signal
460
Adjust expansion valve
470

FIG. 4

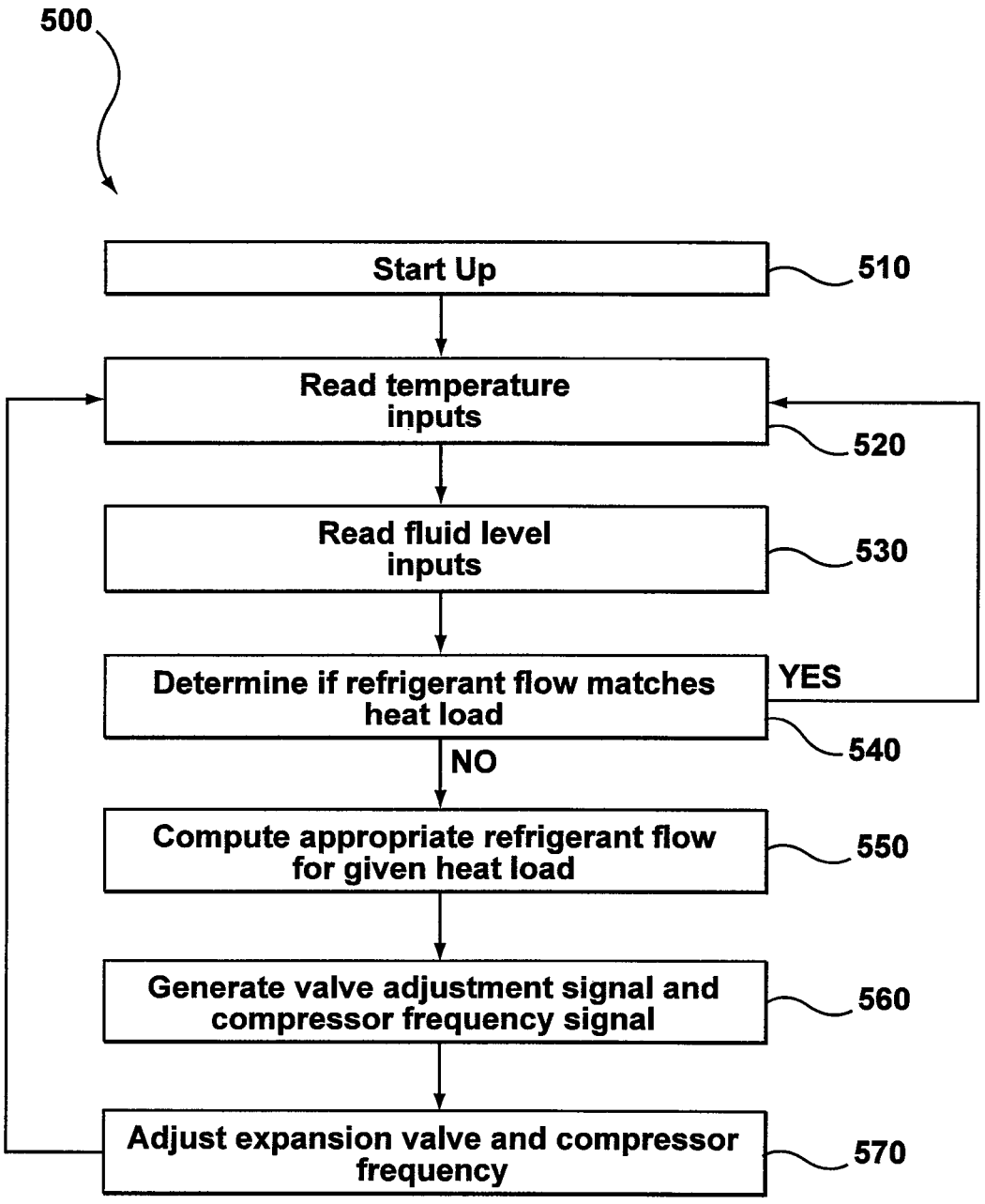

500
Start Up
510
Read temperature inputs
520
Read fluid level inputs
530
Determine if refrigerant flow matches heat load
YES
540
NO
Compute appropriate refrigerant flow for given heat load
550
Generate valve adjustment signal and compressor frequency signal
560
Adjust expansion valve and compressor frequency
570

FIG. 5

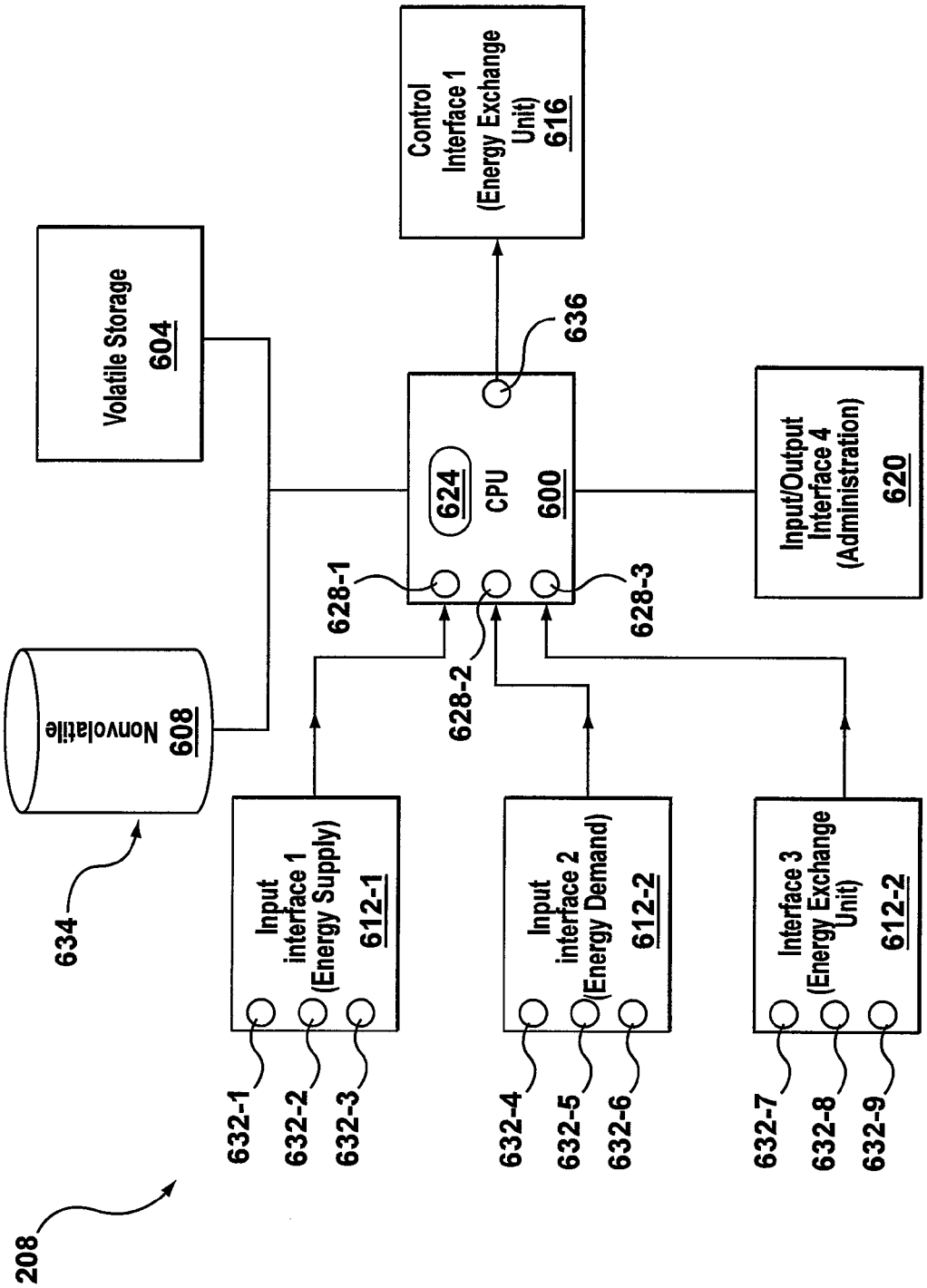

208
634
Nonvolatile 608
Volatile Storage 604
Control Interface 1 (Energy Exchange Unit) 616
636
624 CPU 600
Input/Output Interface 4 (Administration) 620
628-1
628-2
628-3
Input interface 1 (Energy Supply) 612-1
Input interface 2 (Energy Demand) 612-2
Interface 3 (Energy Exchange Unit) 612-2
632-1
632-2
632-3
632-4
632-5
632-6
632-7
632-8
632-9

FIG. 6

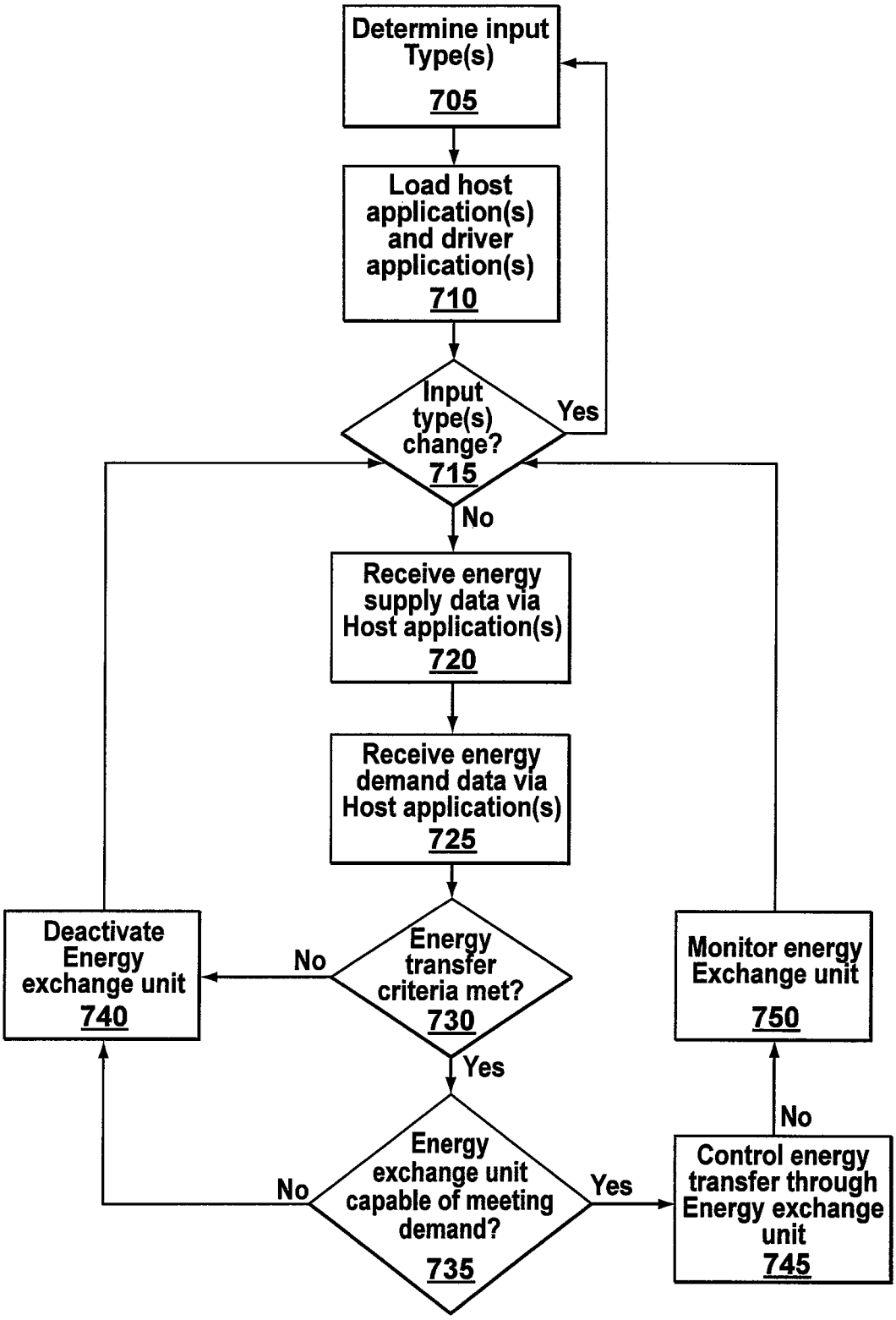

Determine input Type(s)
705
Load host application(s) and driver application(s)
710
Input type(s) change?
715
Yes
No
Receive energy supply data via Host application(s)
720
Receive energy demand data via Host application(s)
725
Energy transfer criteria met?
730
No
Deactivate Energy exchange unit
740
Yes
Energy exchange unit capable of meeting demand?
735
No
Yes
Control energy transfer through Energy exchange unit
745
No
Monitor energy Exchange unit
750

FIG. 7

RETRO-FIT ENERGY EXCHANGE SYSTEM FOR TRANSPARENT INCORPORATION INTO A PLURALITY OF EXISTING ENERGY TRANSFER SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a 35 U.S.C. §371 national stage application claiming priority benefits of International Patent Application No. PCT/CA2010/000605, filed Apr. 16, 2010, which is hereby incorporated herein by reference.

FIELD

The present invention relates generally to energy exchange and distribution systems including heating, ventilation, air-conditioning and water heating, and more particularly relates to a retrofit energy exchange system for transparent incorporation into a plurality of existing energy transfer systems.

BACKGROUND

It is known to employ energy exchange technologies in order to, for example, recover excess heat from an air-conditioning system to provide energy to heat water. The prior art has many examples of such heat-exchange technologies. A cluster of prior art references are also found from the early 1980s which reflect the end of the energy crises of the 1970s. It is interesting to note that these heat-exchange technologies have not been generally adopted, despite their apparent advantages.

SUMMARY

An aspect of this specification provides:

a first set of valves for connection to a first connection point of a first energy transfer sub-system; said first energy transfer sub-system having a potential excess supply of energy available at said first connection point; said first energy transfer system connected a first controller; said first controller configured to receive at least one first input for providing data to said first controller; said first controller configured to send at least one output to said first energy transfer sub-system for selectively instructing activation or deactivation of said first energy transfer sub-system to thereby generate said potential excess supply of energy; said first controller having a passive connection point configured to output a first set data received from said first input;

a second set of valves for connection to a second connection point of a second energy transfer sub-system; said second energy transfer sub-system having a potential demand for energy at said second connection point; said second energy transfer system connected a second controller; said second controller configured to receive at least one second input for providing data to said second controller; said second controller configured to send at least one output to said second energy transfer sub-system for selectively instructing activation or deactivation of said second energy transfer sub-system to thereby realize said potential demand for energy; said second controller having a passive connection point to output a second set of data received from said second input;

an energy exchange unit connectable to said first set of valves via a first conduit; said energy transfer unit connectable to said second set of valves via a second conduit; an energy exchange unit controller connectable to said first energy transfer sub-system and said second energy transfer sub-system to receive said first inputs and said at least one second input; said energy exchange unit controller configured to activate said energy exchange unit when said energy exchange unit controller determines, based on said first input and said second input, that a present excess supply of energy from said first energy transfer system is available to satisfy a present demand for energy at said second energy transfer sub-system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a prior art complete air-conditioning system and separate hot water system for a multi-unit structure.

FIG. **2** shows a retrofit system incorporated into a complete air-conditioning system and separate hot water system for a multi-unit structure.

FIG. **3** shows a schematic representation of an exemplary energy exchange unit that can be used in the system of FIG. **2**.

FIG. **4** shows a flow-chart depicting an exemplary method of operating the energy exchange unit of FIG. **3**.

FIG. **5** shows a flow-chart depicting another exemplary method of operating the energy exchange unit of FIG. **3**.

FIG. **6** shows a schematic representation of a controller for system of FIG. **2**.

FIG. **7** shows a flow-chart depicting another exemplary method a method for controlling energy transfer.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The teachings herein have application to a wide variety of existing energy transfer systems. An example of an energy system is shown in FIG. **1** and indicated generally at **50**. Energy system **50** is incorporated into a multi-unit structure, such as an apartment building or office tower. Thus, a plurality of suites **54**-**1** . . . **54**-*n* are found through-out the structure. Generically, each suite is referred to as suite **54**, while collectively, all suites are referred to as suites **54**-*n*. This nomenclature is used elsewhere herein.) A cooling tower **58** is also provided on the roof of the structure. The structure also comprises at least one indoor common area **62**, such as a hallway or foyer. In FIG. **1**, the structure is also defined in terms of its context in relation to at least one outdoor area **66** that is outside the structure. A mechanical room **70** is also provided in the basement of the structure.

Each suite **74** comprises a heat transfer coil **78**, which is shown in FIG. **1** as operating in an air-conditioning mode whereby energy within hot air HA passing over coil **58** is absorbed by a cold coolant CC-**1** that passes through coil **78**, such that cold air CA exits coil **58** and into suite **54** and hot coolant HC-**1** exits coil **78**, the energy from the hot air HA having been absorbed the cold coolant CC-**1**. Each suite **74** also comprises a hot water demand **82**. Hot water demand **82** can be any one of a sink, shower, or bathtub or other fixture which can receive hot water HW.

Cooling tower **58** comprises a plurality of heat transfer units **86**, each of which can receive hot coolant CC-**2** and transfer energy therefrom into the ambient air on the rooftop and then return cold coolant CC-**2**. Each transfer unit **86** also comprises at least one temperature sensor TS that sends an electronic output therefrom representing a temperature reading of the ambient air on the rooftop or the temperature of hot coolant CC-**2** or cold coolant CC-**2** or all of them.

Indoor common area **62** comprises at least one temperature sensor TS-**7** that sends an electrical output representing a

temperature reading of the ambient air of that common area. Note that indoor common area **62** can, in variations, comprise a heat transfer coil **78**.

Outdoor area **66** comprises at least one temperature sensor TS-**8** that sends an electrical output representing a temperature reading of the ambient air respective to the location of that temperature sensor TS-**8**. Note that where a plurality of temperature sensors TS-**8** are provided, each of those sensors may be located on different sides and heights of the structure, such that the actual temperature reading from each can vary substantially according to time of day and when a particular temperature sensor is exposed to sun, shade, wind or other environmental variables.

Mechanical room **70** comprises a central energy exchange unit **90** that interconnects cooling tower **58** and transfer coils **78**, where excess energy from hot coolant HC-**1** is transferred to cold coolant CC-**2** to thereby generate hot coolant HC-**2** and cold coolant CC-**1**. A temperature sensor TS-**3** connects to a cold coolant line to sense the temperature of cold coolant CC-**2** as it enters central energy exchange unit **90**. A temperature sensor TS-**4** connects a hot coolant line to sense the temperature of hot coolant HC-**2** as it leaves central energy exchange unit **90**. A temperature sensor TS-**5** connects to another hot coolant line to sense the temperature of hot coolant HC-**1** as it enters central energy exchange unit **90**. A temperature sensor TS-**6** connects to another cold coolant line to sense the temperature of hot coolant CC-**1** as it leaves central energy exchange unit **90**.

A first controller **94** receives input from temperature sensors TS, and also connects to central energy exchange unit **90** and to heat transfer units **86** to selectively activate or deactivate central energy exchange unit **90** or heat transfer units **86** or all of them according to temperatures from temperature sensors TS. More specifically, first controller **94** infers demand for cooling from suites **74** via temperature sensor TS-**5** and temperature sensor TS-**6**, while at the same time infers cooling capacity of cooling tower **58** using a remainder of the temperature sensors TS. From such inferences, first controller **94** can selectively activate pumps, compressors and fans associated with central energy exchange unit **90** and heat transfer units **86** to satisfy demand from suites **74**. Controller **94** also typically includes an output port based on a standard format (e.g. RJ45/Ethernet, or Universal Serial Bus, or RS-232, or the like) for monitoring controller **94**.

The foregoing description of the structure and operation of transfer coils **78**, central energy exchange unit **90** and heat transfer units **86** are intended to capture a generic cooling system that can be employed to provide a cooling system for suites **74**. It is to be understood, however, that the actual implementations vary according a number of variables, including the size of suites **74**, the size and manufacturer of transfer coils **78**, central energy exchange unit **90**, heat transfer units **86**, and first controller **94** and the climate in which the structure is located. Those skilled in the art will appreciate that first controller **94** is uniquely programmed according to the unique installation for a given structure and combination of transfer coils **78**, heat transfer units **86**, temperature sensors TS and central energy exchange units **94**. Therefore, notwithstanding the generic description provided, the specific implementation for a given structure will be expected to be different, and possibly substantially different, for each and every structure. Table I shows examples of specific manufacturers and model descriptions that can be employed to implement such a cooling system for suites **74**.

TABLE I

Example components for Cooling System

Common Product Name	Manufacturer	Model	Suitable For
Heat pump	Carrier	25HNA9	Transfer coil 78
Roof top chiller	Carrier	50VL	Heat Transfer units 90
Programmable Logic Controller	Honeywell	2MLR-CPUH/F	First controller 94

Mechanical room **70** also comprises a domestic water heating unit **100** and water tank **104** and that is configured to receive domestic cold water from a municipal water supply **108**. At least one temperature sensor TS-**9** that is associated with tank **104** and is able to determine water temperature(s) associated with tank **104**. Temperature sensor TS-**9** is connected to a second controller **112** which in turn connects to heating unit **100**. Second controller **112** is configured to activate or deactivate a heating element (e.g. a gas flame) within heating unit **100** based on temperature sensed at temperature sensor TS-**9**. Temperature sensor TS-**9** thus comprises an output line that sends a temperature signal to second controller **112**. Domestic cold water CW-**1** from supply **108** enters tank and can flow into heating unit **100** where it undergoes an increase in temperature and then domestic hot water HW-**1** flows back into tank **104**. As water demand(s) **82** are activated, hot water HW is drawn from tank **104** to the activated demand (**82**).

Again, the foregoing description of the structure and operation of heating unit **100** and water tank **104** and controller **112** are intended to capture a generic water heating system that can be employed to provide hot water to suites **74**. It is to be understood, however, that the actual implementations vary according a number of variables, including the size of suites **74**, the size and manufacturer of heating unit **100**, water tank **104**, second controller **112**, the temperature of water received from domestic water supply **108**, and the climate in which the structure is located. Those skilled in the art will appreciate that second controller **112** is uniquely configured according to the unique installation for a given structure and combination of heating unit **100**, water tank **104**. Therefore, notwithstanding the generic description provided, the specific implementation for a given structure will be expected to be different, and possibly substantially different, for each and every structure. Table II shows examples of specific manufacturers and model descriptions that can be employed to implement such a water heating system for suites **74**.

TABLE II

Example components for Water Heating System

Common Product Name	Manufacturer	Model	Suitable For
Water Tank	RHeeM	GHE100-130 (A)	Water tank 104
Aquastat	Honeywell	L4006	Second controller 112
Programmable Logic Controller	Honeywell	2MLR-CPUF	Second controller 112
Heating Unit	Burnham	P203	Water heater 100

Referring now to FIG. **2**, a retrofit energy exchange system is indicated at **200**, which becomes part of an energy system **50***a*. Like components in system **50***a* bear like references to their counterparts in system **50**. System **200** comprises an energy exchange unit **204**, an energy exchange controller

208, a first valve 212 for tapping into the cold coolant line carrying cold coolant CC-2, a coolant return line (for carrying cold coolant CC-3) to connect energy exchange unit 204 to first valve 212, a second valve 216 for tapping into the hot coolant line carrying hot coolant HC-3, a coolant supply line (for carrying hot coolant HC-3) that connects energy exchange unit 204 to second valve 216, a third valve 220 for tapping into the cold water line carrying for cold water CW-2, a cold water line (for carrying cold water CW-3) connecting energy exchange unit 204 with third valve 220, a fourth valve 224 for tapping into the hot water line carrying hot water HW-2, and a hot water line (for carrying hot water HW-3) connecting fourth valve 224 to energy exchange unit 204.

As will be discussed in greater detail below, system 200 is "turn-key" and is configured to connect to any combination of different individual components that can be used to implement the components shown in FIG. 1, including, for example, any implementation of various combinations of components from Table I and Table II, without requiring material modification to any of those components.

An example energy exchange unit 204 will now be discussed with reference to FIG. 3. Energy exchange unit 204 generally incorporates the components of a conventional vapour-compression refrigeration cycle, namely a compressor 320, a condenser 322, and an evaporator 324. In addition, energy exchange unit 204 comprises a heat reclamation unit 326. Heat reclamation unit 326 is placed in thermal communication with cold water CW-3 to produce hot water HW-3. Evaporator 324 is placed in thermal communication with hot coolant HC-3 to produce cold coolant CC-3. Condenser 322 can be operated in either an air-cooled format, or a liquid-cooled format. (Where liquid cooled, cold water CW-3 can also be directed to flow over condenser 322, although this is not shown in FIG. 3.) In the air-cooled format, the condenser 22 is placed in thermal communication with ambient air. Each of the above-noted components are provided with suitable tubing and fittings, to permit the cyclical flow of a refrigerant through these components.

Compressor 320 is responsible for moving the refrigerant through the system, and for compressing the refrigerant into a hot, high-pressure refrigerant vapour. Exemplary compressors used in typical vapour-compression systems include reciprocating, rotary screw, centrifugal, scroll, variable-speed and two-speed compressors.

In a typical cycle, refrigerant R flows in the directional order of compressor 320, heat reclamation unit 326, condenser 322, evaporator 324, and back to compressor 320. The vapour-compression system generally described above may comprise additional components for proper and efficient operation. For example, energy exchange unit 204 also comprises a metering device 332 situated between condenser 322 and evaporator 324. Metering device 332 provides a throttling effect to drop the pressure and temperature of the refrigerant, while also controlling the flow of refrigerant into the evaporator 324. Exemplary metering devices include expansion valves (e.g. thermostatic expansion valves) and capillary tubes.

Energy exchange unit 204 can comprise other suitable components, such as accumulators (liquid-vapour separators), compressor (or crankcase) heaters, strainers, driers, and auxiliary heating elements, as generally known in the art. Energy exchange unit 204 can also comprise a range of industry-standard fittings, as well as customized fittings to enable refrigerant maintenance and replacement, system flushing, refrigerant bypass operations, as well as a range of industry-standard operations as would be familiar to one skilled in the art.

In general, during a typical cycle of the water chiller system, refrigerant R is pressurized at the compressor 320, turning it into a high-pressure, high temperature vapour. High-pressure, high temperature vapour then enters the heat reclamation unit 326, transferring a portion of the heat to a second medium, for example the cold water CW-3. As such, cold water CW-3 is heated, and subsequently delivered to tank 104, effectively providing at least some hot water for tank 104 without using heating unit 100. Next, the high-pressure, high-temperature refrigerant R in the form of vapour enters condenser 322 wherein it transfers additional heat to a comparatively cooler medium, (either air or a liquid), causing condensation of refrigerant R into a high-pressure, high-temperature liquid. The high-pressure, high-temperature liquid then exits condenser 322, and is subject to throttling at metering device 332 prior to entry into the evaporator 324. Throttling the refrigerant drops the pressure and temperature of the refrigerant to below that of the water temperature of the second piped water source 330, turning the refrigerant into a low-pressure, low-temperature liquid. As such, heat transfer from hot coolant HC-3 to refrigerant R occurs evaporator 324, at which point the low-pressure, low temperature liquid is turned into a low-pressure, low-temperature vapour. As a result of the heat transfer in the evaporator 324, hot coolant HC-3 becomes cold coolant CC-3 and is returned to energy exchange unit 90, effectively providing at least some cold coolant CC-3 without relying on cooling tower 58. To complete the cycle, the refrigerant in the form of low-pressure, low-temperature vapour passes back to the compressor 320 for a subsequent cycle.

In general, the portion of the cycle between the compressor 320 and the metering device 332 on the side of the condenser 322 is considered the high pressure high temperature region of the cycle. In turn, the portion of the cycle on the side of the evaporator 324 is considered the low pressure low temperature region. As such, energy exchange unit 204 provides for heating at the heat reclamation unit 326 in the high pressure high temperature region, and further provides for cooling at the evaporator 324 in the low pressure low temperature region.

As mentioned above, an exemplary metering device 332 suitable for use in the water chiller system is an expansion valve. In one embodiment, expansion valve 332 is an adjustable expansion valve. Expansion valve 332, and metering devices in general, meter the flow of refrigerant from the high pressure side of the vapour compression cycle to the low pressure side. With an adjustable expansion valve, the metering of refrigerant across this threshold can be varied in accordance with the heat loads of the system. Under conditions of reduced load, such as where a decreased temperature differential across the evaporator 324 is required, less heat is transferred to the refrigerant, reducing the amount of energy available to convert the refrigerant to vapour. Without adjusting the expansion valve 332 to meet the required load, excessive amount is of refrigerant may pass into the evaporator 324, with possible liquid refrigerant passing through and onto the compressor 320. This condition is generally referred to as "flooding", and can damage the compressor 320. In circumstances where there is increased load, a greater amount of refrigerant R is used to handle the increased demand for heat transfer. Insufficient refrigerant R flow into the evaporator 324 can lead to "starvation" at the evaporator 324 and compressor 320. Both circumstances result in reduced overall efficiency, with possible damaging effects to the system.

As shown in FIG. 3, a central control unit 350 (which can be implemented as part of energy exchange controller 208, or central control unit can be implemented as a stand-alone unit

in communication with exchange controller **208**) is used to monitor and control the adjustable expansion valve **332** during operation of energy exchange unit **204**. Central control unit **350** is configured to signal system components, for example the adjustable expansion valve **332** and compressor **320**, based on inputs received from one or more sensors placed on the energy exchange unit **204**. The central control unit **350** comprises a microcomputer comprised of one or more central processing units connected to volatile memory (e.g. random access memory) and non-volatile memory (e.g. FLASH memory). Data input, analysis and functional control processes are received/executed in the one or more processing units comprising the control unit. The microcomputer includes a hardware configuration that can comprise one or more input devices in the form of a keyboard, a mouse and the like; as well as one more output devices in the form of a display, printer and the like.

To assess the heat load of energy exchange unit **204**, refrigerant return tube **334** between is fitted with a temperature sensor **336**. In some embodiments, central control unit **350** may also receive input from a fluid level sensor **338** within the evaporator **324**. Based on inputs from the one or more sensors, the expansion valve **332** can be adjusted to meter a more suitable flow of refrigerant R from the high pressure side of the vapour-compression cycle, to the low pressure side. With the central control unit **350** monitoring the temperature of the exiting vapour from the evaporator **324**, and the fluid level of the refrigerant contained therein, a balance between the extremes of "flooding" and "starvation" of the evaporator **324** and compressor **320** can be established, thereby improving the overall efficiency of the system. In one embodiment, incremental adjustments of the expansion valve **332** achieve a five ° C. differential, allowing energy exchange unit **204** to be efficiently tuned to match the heat load on the system.

The basic operation of one embodiment of energy exchange unit **204** is shown in FIG. **4**. Upon start-up of the energy exchange unit **204** (step **400**), central control unit **350** activates the system components (e.g. compressor, sensors, etc.), and establishes an initial set-up of the adjustable expansion valve **432** that generally matches the expected load encountered on start-up. At step **410**, the central control unit **350** reads inputs from the one or more temperature sensors on energy exchange unit **204**. In the embodiment described above, the temperature sensor **336** provides this input. At step **120**, central control unit **350** reads inputs from the fluid level sensor **338** provided in the evaporator **324**. At step **430**, central control unit **350** uses these inputs to determine if the current metering by the expansion valve **332** matches the heat load on energy exchange unit **204**. If the metering matches the head load, no adjustments to the expansion valve are necessary. If the metering does not match the heat load, then at step **440**, the central control unit **350** computes the appropriate metering for the noted heat load. At step **350**, the central control unit **350** generates and sends a valve adjustment signal to the adjustable expansion valve **332**. At step **460**, the expansion valve adjusts **332** in accordance with the valve adjustment signal, energy exchange unit **204** then returning to step **310** for further monitoring and adjustment as necessary. The central control unit **350** can be programmed to assess the inputs from the various sensors at regular time intervals, for example once every minute, but time intervals less than, or greater than one minute are contemplated.

As will be appreciated, the use of one or more temperature sensors on energy exchange unit **204** need not be restricted to the configuration described above. The configuration described here is merely exemplary, and one can choose to use a different assembly of sensors to provide the central control unit with the necessary information to effect control over energy exchange unit **204**.

As briefly mentioned above, the screw-type compressor is quite effective for use in the water chiller system. In some embodiments, the screw-type compressor, in particular a variable frequency screw-type compressor can provide additional benefits and control to the water chiller system.

As heat loads upon energy exchange unit **204** vary, for example through changes in the flow of cold water CW-**3** or cold coolant CC-**3**, then constant compressor capacity may result in a mismatched flow of refrigerant through the evaporator **224**, resulting in the aforementioned "flooding" or "starvation" conditions. As such, variable frequency compressors, in particular variable frequency screw-type compressors can be used to vary the amount of refrigerant flowing through the evaporator **324** and into the compressor **320**. This form of control is generally known in the art as capacity control.

Control of the variable frequency compressor **320** is provided by the central control unit **350**. Based on inputs provided by sensors, for example the aforementioned temperature sensor **336** and fluid level sensor **338**, central control unit **350** is configured to determine whether or not the current flow of refrigerant R matches the given heat load. On detecting a mismatched flow of refrigerant, the central control unit **350** instructs one or both of the adjustable expansion valve **332** and variable frequency compressor **320** to adjust to the new condition.

(As will be discussed in greater detail below, controller **208** is also configured to ascertain if such control by control unit **350** is no longer sustaining the energy demands of tank **104** or cooling demands of heat transfer unit **90** or both of them, and at which point to automatically disable energy exchange unit **204** such that system **50** operates as described in relation to FIG. **1** so that cold air CA, as demanded, is still provided to suites **74** and hot water HW, as demanded, is provided to suites **74**.)

The operation of energy exchange unit **204** comprising a variable frequency compressor is shown in FIG. **5**. Upon start-up of energy exchange unit **204** (step **500**), the central control unit **350** activates the system components (e.g. compressor, sensors, etc.), and establishes an initial set-up of the adjustable expansion valve **332** and variable frequency compressor **320** that generally matches the expected load encountered on start-up. At step **510**, the central control unit **350** reads inputs from the one or more temperature sensors **336** on energy exchange unit **204**. At step **520**, the central control unit reads inputs from the fluid level sensor **338** provided in the evaporator **324**. At step **530**, central control unit **350** uses these inputs to determine if flow of refrigerant R through matches the heat load on energy exchange unit **204**. If the metering matches the head load, no adjustments to the expansion valve **332** and/or variable frequency compressor **320** are made. If refrigerant R flow does not match the heat load, then at step **540**, the central control unit **350** computes an appropriate flow of refrigerant R for the noted heat load. At step **550**, central control unit **350** generates and sends one or both of a valve adjustment signal and compressor frequency signal to the respective component. The combination of adjustments to the expansion valve and compressor frequency are dependent on a number of factors, including, but not limited to, maintaining the operation of each component with a range of optimal efficiency for the required refrigerant flow. At step **560**, the expansion valve **332** and/or compressor **320** adjusts in accordance with the respective signals, the system then returning to step **510** for further monitoring and adjustment as necessary. As previously stated, the central control unit **350** can be programmed to assess the inputs from the various

sensors at regular time intervals, for example once every minute, but time intervals less than, or greater than one minute are contemplated.

In some embodiments, the energy exchange unit **204** can further comprise other mechanical/electrical components to enhance the operation and or efficiency of the system. For example, to facilitate the movement of air across the condenser, one or more fan units can be implemented. In some embodiments, while presented above as separate components, the heat reclamation unit **326** and the condenser **322**, may be combined into a single unit.

Referring now to FIG. **6**, controller **208** is shown in greater detail. Controller **208** comprises at least one central processing unit (CPU) **600** connected to a volatile storage unit **604** (e.g. random access memory) and a non-volatile storage unit **608** (e.g. a hard disc drive) by a bus. Controller **208** also comprises a plurality of input interfaces **612** that connect to CPU **600** and provide input thereto. Controller **208** also comprises at least one control interface **616** that connects to CPU **600** and is controlled thereby. Controller **208** also comprises an administration input/output interface **620** to which a keyboard and monitor can connect, either directly or indirectly through a network such as the Internet, so that controller **208** can be administered.

CPU **600** is configured to execute a plurality of software processes, making appropriate use of volatile storage unit **604** and non-volatile storage unit **608** as needed. FIG. **6** shows certain of those software processes, though it will be appreciated by those skilled in the art that other processes are also running. It should also be understood that the term software process is non-limiting, and can encompass software objects, libraries, classes and generally refers to any code that configures CPU to perform a particular function. Likewise non-volatile storage unit **608** is shown maintaining certain data records that are accessible to CPU **600**.

Thus, in FIG. **6**, CPU **600** is shown executing an energy exchange unit master control application **624** which receives input data from a plurality of host applications **628**, where each host application **628** corresponds to a respective input interface **612**. Also in FIG. **6**, non-volatile storage unit **608** is shown maintaining an application database **634**, which maintains copies of a plurality of host applications **628**, including copies of the host applications **628** represented within CPU **600** of FIG. **6**. Application database **634** comprises data files that can maintain a data record for a plurality of different types of energy transfer equipment (e.g. hot water heaters, air conditioning units, controllers for the same, etc.). For example, application database **634** can comprises data files for each article of equipment that is listed in Table I and Table II, or data records for additional articles of equipment not shown in Table I and Table II that can be used as energy transfer systems. The data records in application database **634** each correspond to different host applications **628** that are dynamically loadable onto CPU **600** depending on the type of equipment that is connected to input interface **612-1** or **612-2**.

Each input interface **612** comprises at least one hardware port **632**, with each port conforming to a different format (i.e. form factor corresponding to a particular communication protocol). For example, hardware port **632-1** can be a universal serial bus (USB) format, while hardware port **632-2** can be Ethernet or RJ-45 format. Other formats are contemplated, including terminal posts to receive an analog signal representing a temperature from, for example, temperature sensor TS**9**. In general, hardware ports **632** correspond to formats that are standard outputs for controller **94** and controller **112**, or where a controller does not have a standard output, then hardware ports conform correspond to an output from a temperature sensors TS that supplies that controller **112**.

In a specific exemplary embodiment of FIG. **2** through FIG. **6**, assume that controller **94** is a commercially available with a standard Ethernet output port, in which case then hardware port **632-1** of input interface **612-1** can be an Ethernet port to receive the output from controller **94**. By the same token, assume that while controller **112** is a commercially available Aquastat with an input port to receive data from temperature sensor TS**9**, while hardware port **632-4** of input interface **612-2** can be identical to the input on the Aquastat so as to receive input from temperature sensor TS-**9**.

Continuing with these examples, CPU **600** is configured to load an appropriate host application **628** from database **632** according to the specific controller **94** connected to input interface **612-1** and the specific temperature sensor TS-**9** that is connected to input interface **612-2**. CPU **600** can also be configured to load such a host application **628** automatically (i.e. Plug-and-play) by detecting a particular type of data stream that is available from that hardware port **632**, if such a data stream is uniquely identifiable as corresponding to a particular type of controller **94** or temperature sensor TS-**9**. If the data stream is not uniquely identifiable as corresponding to a particular type of controller **94** or temperature sensor TS-**9**, then CPU **600** can be configured to receive a manual indication of same via input received via administration input/output interface **620**.

In a present embodiment, interface **612-3** is configured to receive an output signal from central control unit **350** that monitors activities of central control unit **350**. Likewise a host application **628** executes on CPU **600** corresponding to central control unit **350**. Control interface **616** also sends an input signal for central control unit **350** via a driver application **636** (which is also stored in application database **634**) that corresponds uniquely to energy exchange unit **204**. In this manner, controller **208** is dynamically configurable to work with different types of energy exchange units, other than energy exchange unit **204**. Master control application **624** thus sits between host applications **628** and driver application **636** to selectively activate or control or deactivate energy exchange unit **204** according to energy demand and supply within system **50***a*.

Referring now to FIG. **7**, a method for controlling energy transfer in accordance is depicted in the form of a flow-chart and indicated generally at **700**. Method **700** can be used to implement master control application **624**. Block **705** comprises determining input types. Block **705** can thus be effected as previously described, whereby master control application **624** examines input signals received via interfaces **612** to determine the type of controller or temperature sensor that is connected interface **612**. Where the determination cannot be made automatically, then block **705** can comprise receiving manual input via interface **620** that identifies the type of input being received via particular interface **612**.

Block **710** comprises loading applications based on the inputs detected at block **705**. As previously described, block **710** thus comprises loading appropriate host applications **628** and driver application **636** from application database **634** to thereby provide software interfaces to the connected controllers or temperature sensors. Such applications **628** and application **636** thus provide master control application **624** with intelligence as to the overall structure and operational parameters of system **50***a*.

Block **715** comprises determining whether there has been any changes to the input types. In other words, block **715** verifies that changes have been made since the detection at block **705**, and if such a change is detected, then method **700**

cycles back to block **705**. If not change is detected then method **700** advances to block **720**.

Block **720** comprises receiving energy supply data via the respective host application(s). In the example above, block **720** comprises examining input received via interface **612-1**, which includes data from controller **94**. Again, it is to be noted that the monitoring of controller **94** is passive—no changes to controller **94** are required—and that built-in monitoring functions of controller **94** are utilized. The data from controller **94** can thus include information from temperature sensors TS-**1** . . . TS-**8**, or information as to whether or not heat transfer units **86** are activated.

Block **725** comprises receiving energy demand data via the respective host application(s). In the example above, block **725** comprises examining input received via interface **612-2**, which includes data from temperature sensor TS-**9**. Again, it is to be noted that the monitoring of temperature sensor TS-**9** is passive—no changes to temperature sensor TS-**9** or controller **112** are required. The data from temperature sensor TS-**9** can thus indicate whether or not a threshold lower temperature has been reached that would normally cause controller **112** to activate heater **100**. Host application **628** can, if desired, be configured with the operational parameters of controller **112** so that master control application **624** can anticipate the operation of controller **112** according to the input from temperature sensor TS-**9**.

Block **730** comprises determining whether an energy transfer criteria has been met. A "yes" determination would be reached at block **730** where, for example, master control application **624** ascertains that one or more heat transfer units **86** are activated AND where temperature sensor TS-**9** has fallen below the threshold lower temperature that causes activation of heater **100**. Other ways of reaching a "yes" determination will now occur to those skilled. Conversely a "no" determination would be reached at block **730** where, for example, master control application **624** ascertains that no heat transfer units **86** are activated.

On a "yes" determination from block **730** method **700** advances to block **735**, at which point a determination is made as to whether the energy transfer unit **204** is capable of meeting the demand that lead to the "yes" determination at block **730**. A "no" determination can be made at block **735** where, for example, a diagnostic exercise reveals that energy transfer unit **204** is in need of a repair or some other fault detection is made. A "no" determination can be made at block **735** where, for example, a diagnostic exercise reveals that even if energy transfer unit **204** is activated, the level of energy required to operate energy transfer unit **204** would not result in any overall net energy savings in system **200***a*. A "no" determination can also be made at block **735** where, for example, a diagnostic exercise reveals that the particular energy demand and supply profiles receive via interfaces **612** will likely lead to the aforementioned "starvation" or "flooding" issues that can occur in the specific, but purely exemplary implementation of energy transfer unit **204** as described above.

Where a "no" determination is made at block **730**, or at block **735**, then method **700** advances to block **740** and energy exchange unit **204** will be deactivated (or will remain inactive if it is already inactive). Method **700** then cycles back from block **740** to block **715**.

Returning again to block **735**, a "yes" determination can be made where, for example, the gap between energy supply and energy demand is so great that even where energy transfer unit **204** operates inefficiently, there will still be a net reduction in the amount of energy consumed by heater **100** that more than offsets the energy consumed by energy transfer unit **204**. Those skilled in the art will now recognize that less cautious criteria can be used to reach a "yes" determination at block **735**.

A "yes" determination at block **735** leads method **700** to block **745**. Block **745** comprises controlling the energy transfer unit. In the specific example above, block **745** can include invocation of method **400** or method **500**, including the variations thereon, so as to heat water for water tank **104**. Other means of controlling the energy transfer unit will now occur to those skilled in the art.

Block **750** comprises monitoring the operation energy transfer unit, to detect faults or any aspects of its operation. While not required, it is generally contemplated that method **700** can comprise heuristic or artificial intelligence algorithms, whereby determinations at block **730** and block **735**, and control parameters used at block **745**, can change based on historic monitoring at block **750** (including historic data from block **720** and block **725**) so that during subsequent cycling of method **700**, the activation, or deactivation, or control over energy transfer unit **204** will change so as to provide the most efficient energy savings profile.

Variants on the foregoing are contemplated. For example, in addition to temperature sensors, other environmental sensors can be added, including sensor for barometric pressure, wind speed, rain fall and the like. As another example, further inputs can be provided to controller **208**, such as a market-feed of daily energy prices—such as electricity costs for the cooling subsystem or natural gas prices for operating heater **100**. Those daily energy price inputs can be further used as part of the determinations made at block **730** or block **735**. As another example, valve **212**, valve **216**, valve **216** and valve **220** can be selectively opened, completely or partially, or closed completely, by remote control from CPU **600** via another control interface (not shown) so as to provide further control over system **50***a*. In this manner, controller **208** can completely remove itself from system **50***a* so that system **50***a* will operate in substantially the same manner as system **50**. Various advantages are contemplated by the teachings herein. For example, as has been noted the incorporation of energy transfer units such as energy transfer unit **204** has been virtually non-existent, despite the basic concepts of such technology being known. The present teachings permit the transparent, passive, non-intrusive introduction of such energy transfer technology with minimal risk for the operator of a multi-unit structure, as much of the prior art contemplates replacement of existing infrastructure with an energy transfer unit capable of satisfying all air conditioning and hot water needs. As another advantage, pricing for the capital costs of retrofitting system **200** into an existing system **50** can be based on a cost-savings model, whereby the cost of system **200** is recouped as a function of overall savings—again encouraging adoption of system **200** with minimal or no risk to the operator or owner of a particular multi-unit structure.

As a still further variation, it should be understood that controller **208** can be configured to work with a plurality of different types of energy supply, and energy demand, and energy transfer technologies. Furthermore, controller **208** can be configured to work with a plurality of energy transfer units and also provided additional inputs to work with a plurality of energy supply sources (e.g. air conditioners, furnaces, ovens, chimneys) and a plurality of energy demands (e.g. hot water heaters, hot air supply sources). In this manner controller **208** can dynamically route different excess energy sources to different energy demands.

Further variations, combinations, and subsets of the foregoing are contemplated. The claims attached hereto solely define the scope of monopoly sought.

The invention claimed is:

1. A retrofit energy exchange system for retrofit installation between an existing first energy transfer sub-system and an existing second energy transfer sub-system, the retrofit energy exchange system comprising:

a first set of valves for connecting to a first set of connection points of said existing first energy transfer sub-system; said existing first energy transfer sub-system having an excess supply of energy available at said first set of connection points; said existing first energy transfer system connected a first controller; said first controller configured to receive at least one first input for providing data to said first controller; said first controller configured to send at least one output to said existing first energy transfer sub-system for selectively instructing activation or deactivation of said existing first energy transfer sub-system to thereby generate said excess supply of energy; said first controller having a first passive connection point configured to output a first set data received from said at least one first input;

a second set of valves for connecting to a second set of connection points of said existing second energy transfer sub-system; said existing second energy transfer sub-system having a demand for energy at said second set of connection points; said existing second energy transfer system connected a second controller; said second controller configured to receive at least one second input for providing data to said second controller; said second controller configured to send at least one output to said existing second energy transfer sub-system for selectively instructing activation or deactivation of said existing second energy transfer sub-system to thereby realize said demand for energy; said second controller having a second passive connection point to output a second set of data received from said at least one second input; and

an energy exchange unit connectable to said first set of valves via a first set of conduits; said energy exchange unit connectable to said second set of valves via a second set of conduits; an energy exchange unit controller connectable to said existing first energy transfer sub-system and said existing second energy transfer sub-system to receive said at least one first input and said at least one second input; said energy exchange unit controller configured to activate said energy exchange unit when said energy exchange unit controller determines, based on said at least one first input and said at least one second input, that a present excess supply of energy from said existing first energy transfer system is available to satisfy a present demand for energy at said existing second energy transfer sub-system.

2. The system of claim 1 wherein said existing first energy transfer sub-system is an air conditioning system.

3. The system of claim 1, wherein said existing second energy transfer sub-system is a hot water heating system.

4. The system of claim 1, wherein said energy exchange controller is additionally configured to dynamically adjust determinations for activating or deactivating said energy exchange unit based on different types of input data from different types of equipment.

5. The system of claim 1, wherein said least one first input comprises input from a temperature sensor connected to at least one connection point of said first set of connection points and for receiving a temperature of coolant associated with said existing first energy transfer sub-system.

6. The system of claim 1, wherein said least one second input comprises input from a temperature sensor connected to at least one connection point of said second set of connection points and for receiving a temperature of hot water associated with said existing second energy transfer sub-system.

7. The system of claim 1, wherein said least one second input comprises input from a temperature sensor connected to a tank of a hot water heating system.

8. The system of claim 1, wherein said first set of valves comprises a first valve connected to a coolant line of an air conditioning system and a second valve connected to said coolant line of said air conditioning system.

9. The system of claim 1, wherein the energy exchange unit comprises:

an evaporator for evaporating a refrigerant using energy from said excess supply of energy;

a compressor for compressing the refrigerant;

a heat reclaimation unit for supplying energy to said demand for energy; and

a condenser for condensing the refrigerant.

10. The system of claim 9, wherein the compressor is a screw-type compressor.

11. The system of claim 10, wherein the compressor is a variable frequency compressor.

* * * * *